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ECOLOGY OF BALD EAGLES WINTERING NEAR A WATERFOWL CONCENTRATION

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Special Scientific Report—Wildlife No. 247

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Ecology of Bald Eagles Wintering Near a Waterfowl Concentration

by

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Abstract

Bald eagles (*Haliaeetus leucocephalus*) associate with wintering waterfowl concentrations throughout the United States, but little detailed information is available on eagle–waterfowl relations. This report concerns the ecology of bald eagles wintering in the vicinity of Swan Lake National Wildlife Refuge in north-central Missouri and, more specifically, examines the association of the eagles with waterfowl during the winters of 1975–76, 1976–77, and 1977–78. Bald eagles were on the study area from October through March; populations peaked in early to middle December at 66 birds in 1975–76, 73 in 1976–77, and 100 in 1977–78. Two or three secondary peaks in eagle numbers occurred during each winter. Waterfowl were on the study area from September to March. Populations of Canada geese (*Branta canadensis*) in the Swan Lake Zone, a 3,625-km² goose management unit, reached peaks of 196,000 birds in 1975–76, 211,400 in 1976–77, and 224,000 in 1977–78. Eagles were closely associated with waterfowl concentrations. Goose hunting in the Swan Lake Zone resulted in large numbers of crippled and dead waterfowl on and near the refuge, and crippled and dead geese were a primary food of wintering eagles. Severe winter weather and low dissolved oxygen in water in refuge impoundments caused large winter kills of fish in 1975–76 and 1976–77. During these two years, eagles ignored waterfowl concentrations after the impoundments thawed, and fed almost exclusively on dead fish. Wintering bald eagles also occasionally preyed on healthy waterfowl and on mammals. In 600 bald eagle regurgitated pellets, Canada geese were by far the most common prey species, and mallards (*Anas platyrhynchos*) ranked second. Among the few mammal species represented in the pellets, cottontail rabbits (*Sylvilagus floridanus*) were the most common. Among 18 radio-tagged bald eagles monitored on the study area for 5 to 75 days, local movements and minimum winter ranges varied widely. Local movements and distribution of eagles near Swan Lake were closely related to those of waterfowl, but the availability of carcasses of waterfowl and fish on or near the refuge was also influential. Each fall, eagles arrived at Swan Lake well after live geese and carcasses became abundant, suggesting that eagles do not pursue the geese southward. Rather, the eagles' southward migration may be occasioned by other phenological events in northern portions of their range, and ultimately, perhaps, by food shortages there.

Numbers of bald eagles (*Haliaeetus leucocephalus*) have slowly declined since the advent of the white man on the North American continent; however, the decline has become more pronounced and rapid since World War II (Sprunt 1968; Snow 1973). Much information has been collected on food, habitat requirements, and population dynamics of northern bald eagles on their breeding grounds (Herrick 1934; Munro 1938; Retfalvi 1965, 1970;

Troyer and Hensel 1965; Grier 1974, Whitfield et al. 1974; and others). Many northern forests are managed for nesting bald eagles (Hager 1974, 1976). However, only recently has attention been focused on the winter ecology of the species, and there has not yet been a major attempt to improve winter habitat. Because habitat destruction and alteration have been more extensive in the wintering range, preservation and sound management of winter habitat may be the most critical factor affecting northern bald eagle populations (Steenhof 1976, 1978).

In studies of the winter ecology of bald eagles, some investigators found that wintering eagles fed primarily on fish, and to a much lesser degree (if at all) on waterfowl: Southern (1963, 1964) and Jonen (1973) in Illinois; Grewe (1966), Steenhof (1976), and Steenhof et al. (1980) in South Dakota; Ingram (1965) in Wisconsin; Shea (1973) in Montana; Lint (1975) in Idaho; Servheen (1975), Stalmaster (1976), and Stalmaster and Newman (1978, 1979) in Washington; and Cooksey (1962) and Lish and Lewis (1975) in Oklahoma. Edwards (1969) and Platt (1976) reported that in Utah the birds fed mostly on jackrabbits (*Lepus californicus*). Other investigators, however, have shown that waterfowl are the major food of bald eagles at some wintering sites. Ducks were the principal food of bald eagles wintering near Bear River Migratory Bird Refuge in Utah (Swisher 1964). In New Brunswick, a population of bald eagles changed from their primary diet of fish and carrion in summer to waterfowl in winter (Wright 1953). In British Columbia, bald eagles preyed on crippled ducks (Munro 1938). Many Federal and State waterfowl areas attract bald eagles, particularly after the hunting season, when crippled ducks and geese are available as food (Snow 1973). Biologists and refuge managers throughout the United States have reported bald eagles associating with wintering waterfowl (Spencer 1976). Yet, little detailed information is available about eagle–waterfowl relations.

Swan Lake National Wildlife Refuge, in north-central Missouri, harbors a large wintering population of Canada geese (*Branta canadensis*) and a large winter concentration of bald eagles. Eagles are apparently attracted to the refuge by mild winter weather and large numbers of wintering waterfowl. Historically, as the number of waterfowl wintering in the area increased, so did the number of eagles. Similar trends in numbers of waterfowl and eagles have been reported at three other wildlife refuges in the Midwest (Griffin et al. 1980).

The present study was designed to investigate the ecology of bald eagles wintering in the vicinity of Swan Lake Refuge, and especially the factors that influence the association of bald eagles with wintering waterfowl.

Study Area

The study area encompasses about 260 km² in Chariton, Carroll, Linn, and Livingston counties in north-central Missouri. It includes Swan Lake National Wildlife Refuge, Swan Lake Wildlife Management Area, Fountain Grove Wildlife Management Area, and the Grand River between Swan Lake and Fountain Grove (Fig. 1). The entire study area lies within Swan Lake Zone, described below.

Swan Lake National Wildlife Refuge (NWR) is 3 km east of the Grand River, and 23 km north of the confluence of the Grand and Missouri rivers. It is a 4,455-ha area developed and managed by the U.S. Fish and Wildlife Service. About 2,000 ha of the refuge consist of open water in three major impoundments. At the time of our study (1975–78), 1,215 ha were cultivated for wildlife food. Major crops were corn, milo, and winter wheat. An additional 405 ha of the refuge were in grass–legume fields and up to 325 ha of naturally produced moist-soil plants were available. Much of the rest of the refuge is oak–hickory and mixed timber along the streams and drainage ditches (Babcock et al. 1978).

Swan Lake Wildlife Management Area is a 0.4-km-wide strip of land lying within the perimeter of Swan Lake NWR. It has been leased and managed for goose hunting by the Missouri Department of Conservation in cooperation with the U.S. Fish and Wildlife Service since 1955.

Fountain Grove Wildlife Management Area, 11.5 km northwest of Swan Lake NWR, is a 2,185-ha tract of State-owned land managed intensively for waterfowl by the Missouri Department of Conservation and is a public hunting area. It includes 810 ha of shallow water in three major pools. Crop production for wildlife consists of about 535 ha of corn, wheat, and milo. Bottomland forest borders much of the river and streams on the area (Babcock et al. 1978).

Swan Lake Zone, a 3,625-km² Canada goose management unit, surrounds Swan Lake NWR and Fountain Grove Wildlife Management Area. The Zone attracts the largest concentration of the Eastern Prairie Population of Canada geese in the Mississippi Flyway. Swan Lake NWR and Fountain Grove Wildlife Management Area provide habitat for these geese during the fall hunting season, and supply about 50% of their winter food requirements (Babcock et al. 1978).

Materials and Methods

Field work extended from October through March during three field seasons: 1975–76, 1976–77, and 1977–78. In 1975–76 and 1977–78, observations were made daily when work schedules and weather permitted, but in 1976–77 observations were limited to 2 days per week.

Counts of Eagles, Geese, and Carcasses

Weekly counts of eagles were made on the Swan Lake NWR from October through March when weather and

access to the refuge interior permitted. Counts were made from a vehicle with binoculars or a spotting scope. Although all-weather roads on the refuge provided a route from which most eagles could be counted, some parts of the refuge were not accessible for census. Most counts were made between 0630 and 1100 hours, when eagle congregations were usually largest. Counts were not made if weather was severe or if visibility was limited by fog or precipitation. If the entire head and tail of a bird were white, it was classed as an adult; all others were classed as immatures. We made 22 counts of eagles on Swan Lake NWR in both 1975–76 and 1976–77, and 17 in 1977–78. No counts were made from late October to mid-December 1977 because of limited access to the refuge interior.

Aerial waterfowl inventories were conducted periodically during the three winters by the Missouri Department of Conservation. Surveys of Canada goose numbers in the Swan Lake Zone were made between September and January.

In 1975–76 and 1976–77, we made counts of waterfowl and fish carcasses along shoreline transects on the refuge. In 1977–78, early freeze-up on the refuge, wide dispersal of waterfowl in the Swan Lake Zone, and limited access to the interior of the refuge during the hunting season, prevented us from making adequate waterfowl carcass counts. Additionally, no fish kill occurred on the refuge in 1977–78. All waterfowl and fish count transects extended 4.2 km along the west shore of Silver Lake, and a fish transect also extended 1.3 km along the northwest shore of South Pool (Fig. 1). Due to waterfowl use of ice-free openings in the middle of refuge impoundments, transect counts did not always accurately reflect relative numbers of waterfowl carcasses available to eagles. Transects were selected for their accessibility and abundance of carcasses. When possible, transects were systematically examined from a vehicle and on foot on the same day on which eagles were counted. Carcasses thoroughly stripped of meat were not counted.

Feeding Habits

Feeding activities of eagles were observed throughout the study period. Roosting sites and feeding perches were periodically searched for discarded food and cast pellets. Species represented among waterfowl and fish carcasses along carcass transect lines were identified. Cast pellets were analyzed by methods described by Errington (1932). Mammalian prey items in pellets were identified by using the key to guard hairs published by Stains (1958).

Capture

Eagles were trapped in the field seasons of 1975–76 and 1977–78 with specially designed leg-hold traps, concealed around anchored Canada goose carcasses; a live decoy bald eagle was often used (Griffin 1978). Trapping sites were in fields and on frozen impoundments adjacent to eagle feeding areas and perches. All captured unbanded eagles were banded with U.S. Fish and Wildlife Service rivet-type bands.

Radiotelemetry

Radio transmitters were placed on 6 captured bald eagles in 1975–76 and 12 in 1977–78. Sixteen of the transmitters (manufactured by AVM Instrument Company, Champaign, Illinois) were powered by lithium batteries (SB-2), and the other two (Telemetry Systems, Inc., Milwaukee, Wisconsin) by solar cells and rechargeable mercury batteries. Transmitters operated in the 150–151 MHz band and each was identifiable by a distinct frequency and pulse rate (48 to 120 pulses per min). The six transmitter units placed on eagles in 1975–76 were encased in blue Herculite plastic to increase their visibility and protect them from damage by the eagle and weather. The Herculite casings covered the entire transmitter unit, including the antenna. The size (42 g) of the units necessitated a back-mounted harness system on the eagles.

A 12-channel receiver (AVM Instrument Company) was used with either a hand-held four-element yagi antenna or a four-element yagi null-peak antenna system attached to a vehicle. When daily ground searches by vehicle failed, we made aerial searches using two yagis, one on each strut of a Cessna 172.

Depending on weather and road conditions, radiotracking was attempted at least twice a day by ground triangulation. Ten aerial searches were made. Locations were made from 0600 to 2200 hours; most were made from 0700 to 1100 and 1500 to 1900. All available radio fixes and visual sightings were plotted on acetate laid over aerial photos of the study area. Minimum local winter range size was determined by a modification of the "minimum home range" method of Mohr (1947).

Results

Eagle Populations

Numbers and Annual Chronology

Bald eagles occurred in the Swan Lake Zone from October through March. In each of the three fall and winter seasons, numbers fluctuated considerably; the population was characterized by three or four distinct peaks, separated by lows of varied length and degree.

In 1975–76, the first bald eagle was sighted on the refuge on 2 October. Four major peaks occurred during fall and winter (Fig. 2). The first and highest (66 birds) occurred on 2 December. Numbers declined to 37 on 8 December, increased to a second peak of 58 on 18

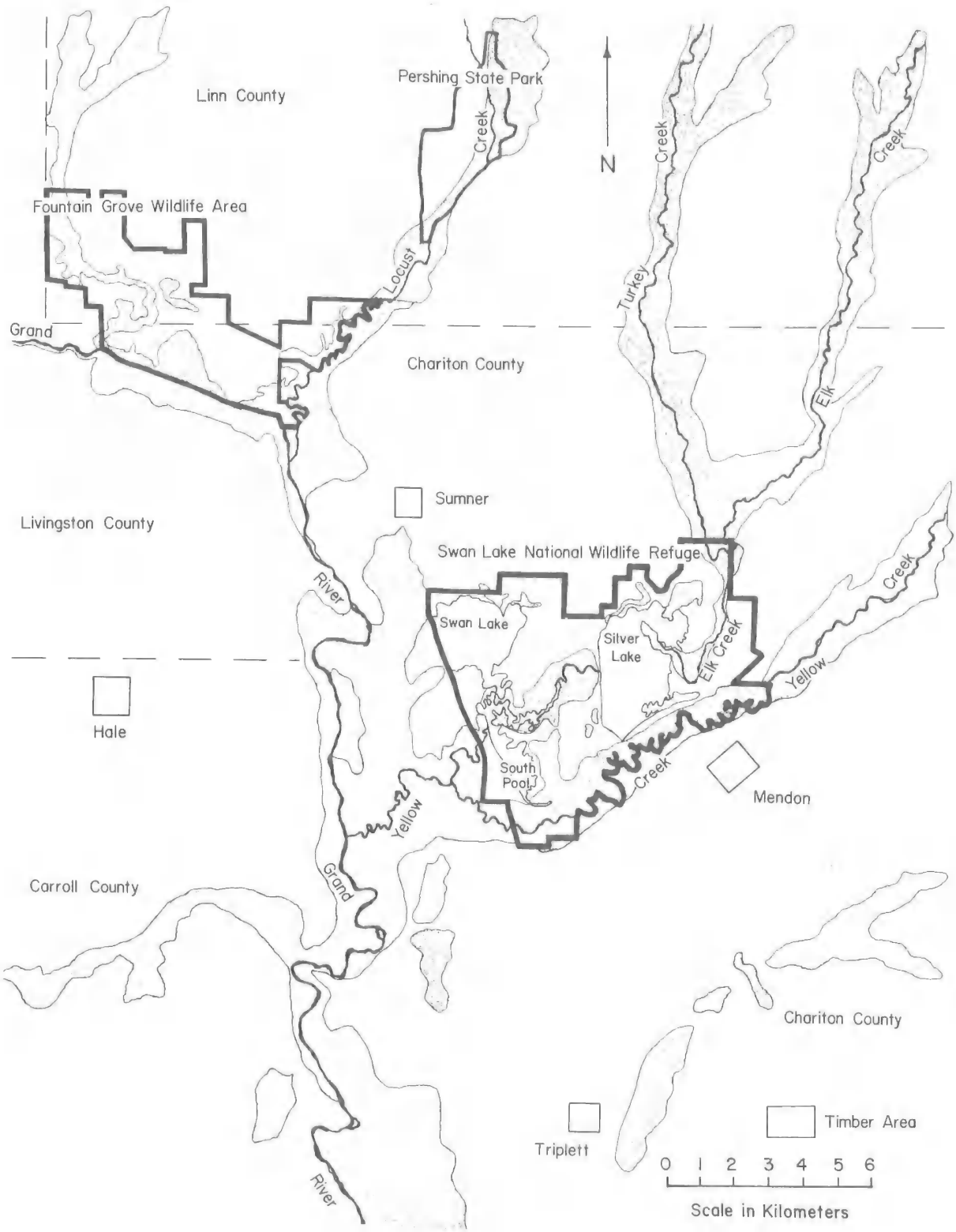

Fig. 1. Study area, Swan Lake National Wildlife Refuge and vicinity.

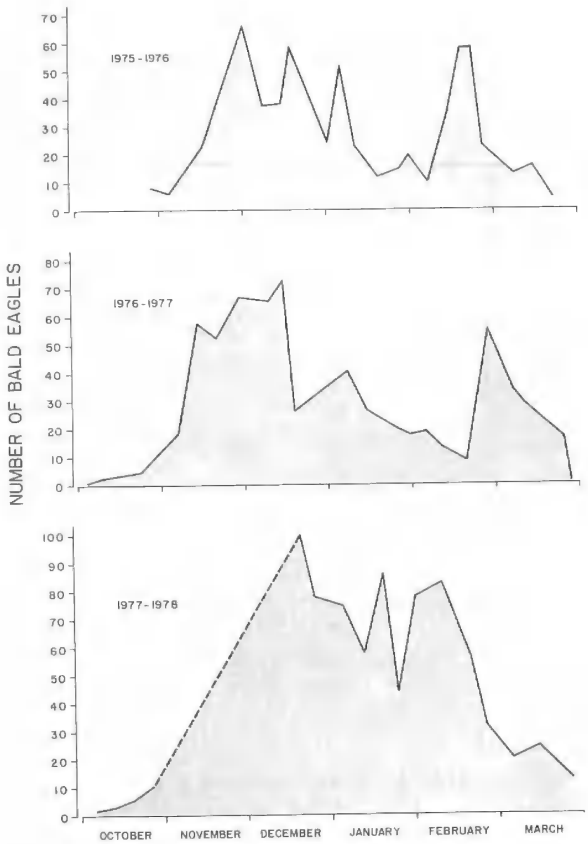

Fig. 2. Number of bald eagles counted on Swan Lake National Wildlife Refuge on different dates, October–March 1975–78 (no counts 24 October to 19 December 1977).

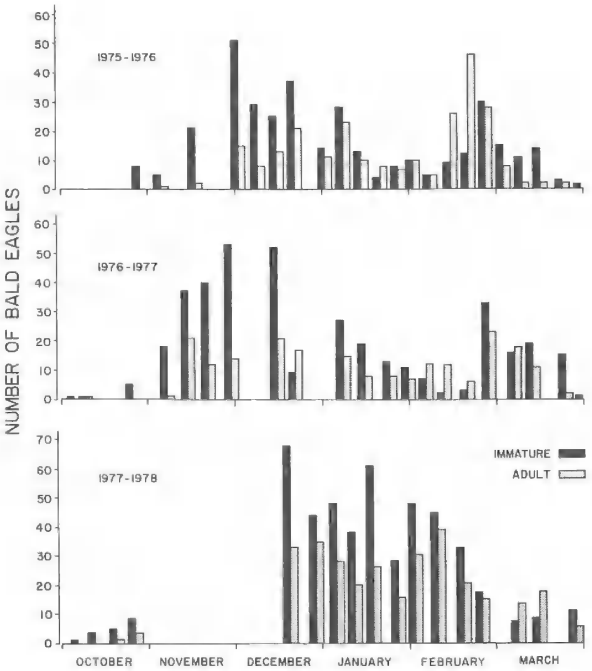

Fig. 3. Age ratio patterns of wintering bald eagles, 1975–78, Swan Lake National Wildlife Refuge.

December, dropped to 25 on 1 January, and then quickly increased to 51 on 6 January. After this third peak, eagle numbers declined almost steadily to 10 by 7 February, but then again increased to the fourth major peak (58) on 19 February. Thereafter the population decreased rapidly through late February and March.

In 1976–77, the first eagle was seen on the refuge on 3 October, and three major peaks followed (Fig. 2). The first and largest was 73 birds on 14 December; numbers then declined abruptly to 26 on 18 December, rose to 41 on 7 January, and then again declined. The final peak (56 birds) occurred on 27 February. The population then fell steadily through March.

In 1977–78, the first eagle was seen on the refuge on 5 October, and three major population peaks followed (Fig. 2). The first and largest peak was 100 birds on 19 December. Numbers then declined to 58 on 11 January, climbed to 87 on 17 January, declined to 43 on 27 January, increased to 83 on 9 February, and then fell steadily through March.

Although these population figures are minimums because not all areas of the refuge were accessible for censusing, we believe they closely approximate the actual eagle numbers on the refuge.

The average numbers of eagles on the refuge were similar in the first two field seasons—27.3 eagles per survey in 1975–76 and 29.8 in 1976–77—but differed greatly (45.1 per count) in 1977–78, when the peaks and the lows were both substantially higher than in the first two seasons.

Age Ratio Patterns

Age ratios of bald eagles on the refuge varied throughout each fall and winter. Age ratio patterns were similar in the early season during the three field seasons, but after December the patterns in 1975–76 and 1976–77 differed from that in 1977–78 (Fig. 3). During all three seasons, immature eagles arrived first in the fall and rapidly increased in numbers. Adults were less abundant in fall and early winter. In December, when eagle numbers peaked, 67 to 77% were immatures.

In 1975–76 and 1976–77, numbers of immatures and adults were roughly equal in late January. In February the numbers of adults increased rapidly and then quickly declined through March. Numbers of immature eagles also increased rapidly in late February and declined less rapidly than adults. Excluding the time of spring migra-

Table 1. *Periodic inventories of Canada geese, Swan Lake National Wildlife Refuge and Swan Lake Zone, 1975–78.* (Data from Missouri Department of Conservation, Columbia, Missouri.)

Date (1975–76)	Refuge total	Zone total	Date (1976–77)	Refuge total	Zone total	Date (1977–78)	Refuge total	Zone total
29 Sep	50,075	51,725	9 Sep	21,700	42,750	27 Sep	2,150	2,150
6 Oct	79,325	99,850	12 Oct	77,400	92,300	3 Oct	42,000	42,500
20 Oct	136,125	166,475	25 Oct	140,500	179,200	11 Oct	36,250	39,250
27 Oct	108,000	185,000	1 Nov	146,600	169,625	17 Oct	79,600	108,250
10 Nov	145,900	173,925	8 Nov	147,800	175,200	26 Oct	104,200	113,250
17 Nov	154,850	171,350	15 Nov	149,900	170,025	7 Nov	106,800	111,650
1 Dec	101,650	196,000	22 Nov	162,900	179,675	14 Nov	125,700	137,900
15 Dec	36,500	174,600	29 Nov	177,725	195,825	21 Nov	98,600	116,175
5 Jan	300	180,025	13 Dec	66,600	211,375	28 Nov	156,000	164,650
			20 Dec	43,450	197,225	12 Dec	80,100	120,600
			5 Jan	10,350	160,125	19 Dec	107,300	157,950
						3 Jan	181,300	224,000

tion (late February through March), the ratio of adults to immatures was greatest during the periods of harshest weather and low food availability on the refuge.

In 1977–78, after the December peak, numbers of immatures declined somewhat and then remained nearly stable until mid-January, when they increased and made up 70% of the eagle population on the refuge. Percentages of adults ranged from 30 to 45 during mid-December to mid-January and from 35 to 68 during mid-January to mid-March. However, the percent increase in March occurred while total numbers of eagles were declining. From mid-January to early March, numbers of immature eagles in the population gradually decreased. Numbers then remained relatively stable until birds left the refuge in late March. Age ratio patterns and total eagle population numbers were relatively more stable during this field season than in 1975–76 and 1976–77.

Canada Goose Populations

Migrant waterfowl began arriving in the Swan Lake Zone in mid-September, remained throughout winter, and left in March. During this study, 32 aerial Canada goose inventories were conducted by the Missouri Department of Conservation from September to early January: 9 in 1975–76, 11 in 1976–77, and 12 in 1977–78 (Table 1).

Canada goose populations on Swan Lake NWR in the successive field seasons peaked at 154,850 birds on 17 November 1975; 177,725 on 29 November 1976; and 181,300 on 3 January 1978 (Table 1). Peaks for the entire Swan Lake Zone came 2 weeks later in 1975–76 and 1976–77, and on the same date in 1977–78 (Table 1).

Waterfowl distribution and concentration in the Swan Lake vicinity were affected by weather, habitat conditions (including water and food availability), and hunting pressure. After the waterfowl hunting season began, geese concentrated on the refuge, but after closure of the hunting season, onset of severe winter weather, or depletion of food supplies, they moved to the Missouri and Grand rivers or to other locations outside the Swan Lake Zone. However, when standing corn and milo were mowed on the refuge in January each year, waterfowl concentrated in these fields, where the grain had previously been largely inaccessible to them. Large numbers of waterfowl used the refuge briefly during the spring migration in March.

Carcasses of Waterfowl and Fish Available

Canada goose crippling loss from waterfowl hunting in the Swan Lake area was estimated to be 20% of the total harvest by Vaught and Kirsch (1966). Consequently many crippled and dead waterfowl are concentrated on and near the refuge. Many crippled geese die in fields or in impoundments, where they wash ashore. Their numbers are augmented by diseased birds. Our waterfowl carcass counts along a transect yielded relative numbers of waterfowl carcasses available to eagles. We made 10 such counts in 1975–76 and 15 in 1976–77 (none in 1977–78; Table 2).

Each year the goose hunting season opened in late October (25–29 October during our 3-year study), and lasted until the goose harvest quota for the Swan Lake Zone or the scheduled end of the goose hunting season was reached (usually early December; early January in 1977–78). Approximately 25,000 geese were harvested in 1975–76, and 20,000 in 1976–77 and 1977–78.

In 1975–76, 11 waterfowl carcasses were seen along the refuge transect on 20 October when the first count was made; numbers increased rapidly to a peak of 89 on 4 November, and then decreased to nil by 11 January.

In 1976–77, 6 carcasses were seen on 6 November, 14 on 28 November, and (after freezing weather and snow) 2 on 14 December. Carcass numbers then rose to 28 by 18 December, after waterfowl use of the refuge had increased during warm, thawing weather, and snow-covered carcasses became visible as the snow melted. Carcass numbers then declined to zero by 7 January. Again,

Table 2. *Numbers of waterfowl and fish carcasses counted along sections of shoreline, Swan Lake National Wildlife Refuge, 1975–77.*

Date (1975–76)	No. of carcass	Date (1976–77)	No. of carcass
Waterfowl		Waterfowl	
20 Oct	11	3–23 Oct (3)[a]	0
4 Nov	89	6 Nov	6
2 Dec	48	20 Nov	6
9 Dec	40	28 Nov	14
18 Dec	26	14 Dec	2
1 Jan	15	18 Dec	28
11–31 Jan (4)	0	7 Jan	0
		14 Jan	9
		23 Jan	8
		29 Jan–19 Feb (4)	0
Fish		Fish	
9 Feb	33	27 Feb	1,057
10 Feb	850	6 Mar	1,100
16 Feb	4,100	10 Mar	826
1 Mar	1,680	24 Mar	384
8 Mar	1,250	27 Mar	596
15 Mar	875		

[a]Numbers of counts during the period between the inclusive dates are in parentheses.

severe cold weather and snow occurred, and about 60 Canada geese on Silver Lake died, apparently from winter stress. When the next carcass count was conducted on 14 January, only 9 of the carcasses had not been eaten. In surveys on 29 January and thereafter, no carcasses were seen.

Waterfowl carcasses were counted on a 48-ha field along the west border of the refuge in January 1976, when refuge personnel mowed standing corn and milo. About 100 carcasses were seen, suggesting that large numbers of waterfowl carcasses were probably available in refuge fields.

After increases early in the hunting season, our counts of carcasses declined or fluctuated erratically (Table 2) because the numbers were highly dependent on waterfowl use of the refuge, which in turn depended primarily on weather.

Severe winter weather and poor water conditions (low water level, high turbidity, and low dissolved oxygen) caused large fish kills on the refuge in 1975–76 and 1976–77. When exposed by thaws, fish that had been frozen in the ice were eaten by eagles. Our transects yielded counts of relative numbers of fish carcasses available to eagles. Most fish counted were 15 cm or longer. Six counts were made in 1975–76 and five in 1976–77 (Table 2). Thirteen species of fish were identified among the carcasses: paddlefish (*Polyodon spathula*), shortnose gar (*Lepisosteus platostomus*), gizzard shad (*Dorosoma cepedianum*), mooneye (*Hiodon alosoides*), common carp (*Cyprinus carpio*), bigmouth buffalo (*Ictiobus cyprinellus*), river carpsucker (*Carpiodes carpio*), channel catfish (*Ictalurus punctatus*), builhead (*Ictalurus* sp.), largemouth bass (*Micropterus salmoides*), white crappie (*Pomoxis annularis*), bluegill (*Lepomis macrochirus*), and drum (*Aplodinotus grunniens*).

In 1975–76 the spring thaw began in early February, and 33 fish carcasses were counted along transects on 9 February. Numbers increased rapidly as the ice broke up and peaked at 4,100 on 16 February. They then declined steadily through early spring. In 1976–77 the spring thaw began in late February. Fish carcasses along transects numbered about 1,100 on 27 February and 6 March and then declined steadily through March. Refuge personnel estimated the fish kill at the refuge at 200,000 fish in 1975–76 and 100,000 in 1976–77. Optimal water levels on the refuge before freeze-up probably prevented a fish kill in 1977–78.

Before our study, there were only two records of winter fish kills on the refuge. One occurred in the winter of 1968–69, and the other in the winter of 1973–74 (M. F. Lentz, personal communication). The increasing shallowness of the impoundments from siltation, combined with low water conditions in fall contributed to these kills (B. M. Hull, personal communication).

Feeding Habits of Eagles

Waterfowl as a Food Resource

From October into January during the three seasons of our study, dead waterfowl constituted the primary food of bald eagles. Eagles fed primarily on Canada goose carcasses; fewer carcasses of snow geese (*Chen caerulescens*), mallards (*Anas platyrhynchos*), green-winged teal (*A. crecca*), and pintails (*A. acuta*) were available on the refuge. Eagles fed on carcasses along refuge impoundment shorelines or frozen in the ice. After most of these were eaten, the birds relied heavily on carcasses in refuge fields; however, these did not become accessible to eagles until the fields were mowed in mid-January.

Crippled and diseased waterfowl, especially Canada geese, were also important sources of food. Weakened waterfowl were readily attacked and eaten. Although many attempts by eagles to kill apparently healthy waterfowl were noted each winter, we saw only five that were successful: twice an immature eagle captured a duck in flight soon after flushing a flock from the lake; an adult eagle caught one duck as it flushed from the ice; an immature eagle flew into a flock of mixed waterfowl on the ice and captured a duck; and an immature eagle forced a snow goose down into a field and fed on it. Although these observations are few, we believe that eagles prey on healthy waterfowl regularly at Swan Lake. Defensive tactics that waterfowl employ when an eagle comes near further suggest that they are attacked by eagles.

Ducks and coots (*Fulica americana*) were pursued by eagles over water; Canada geese were pursued over both water and fields. When an eagle approached, snow geese, ducks, and coots appeared to be more restless and flushed sooner than Canada geese, possibly reflecting the greater vulnerability of the smaller birds. All waterfowl species appeared to flush sooner at the approach of an eagle when impoundments were frozen, possibly indicating increased vulnerability on ice. Eagles usually ignored waterfowl concentrations after the spring thaw if winter-killed fish were available; however, they were seen diving on ducks as late as 3 March, and harassing a dying goose on 13 March (in 1976). In spring 1978, when no winter fish kill occurred, feeding on waterfowl continued until the eagles left the area.

Fish as a Food Resource

Fish replaced waterfowl as the principal food of eagles after winter-killed fish were exposed by thaws. We did not see eagles capture live fish, and few fish carcasses were found under eagle perches during fall and early winter, when waterfowl were the primary food. Thus, during the first two seasons of study, fish were not an important food at Swan Lake until several months after the eagles arrived. And in the third season when there was no winter kill, fish were never a major food of eagles at Swan Lake. Under the circumstances of our study, fish became important only when adverse water conditions caused massive fish kills, followed by thaws that made the carcasses available. When these prerequisites were met, eagles fed almost exclusively on fish.

Feeding Behavior

After leaving night roosts, most eagles arrived at feeding areas during the half hour before sunrise. Feeding sites were used consistently each day until food at the site was depleted or made unavailable by snow or freeze-up. Feeding began intensely as soon as light allowed and continued until about 1000 hours. When prey was abundant, eagles sometimes began feeding again in late afternoon and continued until they returned to night roosts. After a day of such intense feeding, feeding on the following day seemed to be reduced. When prey was scarce, eagles were seen feeding and searching for food throughout the day. Blizzards during the day either forced eagles to stay in the immediate vicinity of the night roost or severely restricted their feeding.

Feeding was highly communal. However, even though a few (2 or 3) to more than 30 eagles fed close together, they rarely shared the same food item. Because waterfowl and fish carcasses were too heavy for eagles to carry, they were eaten on the ground or on the ice. When food was in shallow water, eagles waded to carcasses and dragged them to shore or onto a low perch before feeding. The birds sometimes gathered small carcasses from the water, frozen impoundments, or shore by swooping upon them without landing. Eagles commonly displaced each other from carcasses and perches at feeding areas (Griffin 1981).

Eagles often attacked crippled and diseased waterfowl. In one instance, as many as 32 eagles surrounded and harassed a crippled Canada goose. Individual eagles approached the goose and attacked it until the goose drove them off. After several hours, however, the goose weakened and was eaten. When preying on crippled ducks, eagles flew low over prey on water or ice. As the eagle approached, healthy ducks flushed, but crippled ducks that were unable to fly remained to be attacked by the eagles.

Pellet Analysis

In 1975–76 and 1976–77, pellets regurgitated by bald eagles were collected beneath night roosts and diurnal perches on Swan Lake NWR. Of 1,206 pellets collected, 600 (300 from each field season) were selected at random and analyzed for prey remains.

Remains of birds were far more common in pellets than remains of mammals. Bird parts occurred in 599 pellets and mammal parts in only 22. Seven species of birds and six species of mammals were represented (Table 3).

Canada goose remains were by far the most common avian species in pellets in both years, occurring in 527 of the 600 pellets. Remains of mallards ranked second (in 211 pellets), snow geese third (23 pellets), and coots fourth (11 pellets). Cottontail rabbits (*Sylvilagus floridanus*) were the most common mammal represented, occurring in 11 of 22 pellets that contained evidence of mammalian species (Table 3).

Fish remains occurred in only 35 pellets. However, few fish remains were expected, inasmuch as Steenhof (1976) reported that when eagles are feeding predominantly on fish, all remains are digested and there is no pellet cast.

Pellet analysis clearly indicated that Canada geese were by far the most important food of eagles. The high frequency of occurrence of mallard remains suggested that mallards were fed upon more commonly than our field observations indicated.

Of 1,206 pellets analyzed for lead shot, only 113 contained one or more shot (Griffin et al. 1980). This low frequency of occurrence implied that eagles were feeding mainly on healthy waterfowl, but field observations indicated that they fed most heavily on crippled and dead waterfowl that resulted from waterfowl hunting (Griffin et al. 1980). The true contribution of hunter-killed or crippled waterfowl as eagle food remains unresolved. Recent work by the Missouri Department of Conservation has shown that 35% of the Canada goose losses at Swan Lake NWR in 1980 were due to combinations of lead poisoning, fowl cholera, aspergillosis, and esophageal impaction (D. D. Humburg, personal communication).

Table 3. *Frequency of occurrence of food species in 600 cast pellets of bald eagles (300 each in 1975–76 and 1976–77), Swan Lake National Wildlife Refuge.*

Category and species	1975–76	1976–77	Total
Birds			
Canada goose (*Branta canadensis*)	286	241	527
Snow goose (*Chen caerulescens*)	8	15	23
Mallard (*Anas platyrhynchos*)	81	130	211
Pintail (*Anas acuta*)	2	1	3
Green-winged teal (*Anas crecca*)	0	3	3
American coot (*Fulica americana*)	3	8	11
American bittern (*Botaurus lentiginosus*)	0	1	1
Mammals			
White-tailed deer (*Odocoileus virginianus*)	0	1	1
Muskrat (*Ondatra zibethicus*)	4	2	6
Cottontail (*Sylvilagus floridanus*)	9	2	11
Raccoon (*Procyon lotor*)	1	0	1
Fox squirrel (*Sciurus niger*)	1	0	1
Deer mouse (*Peromyscus maniculatus*)	0	2	2
Fish	25	10	35

Local Movements of Eagles

Local movements of 18 radio-tagged bald eagles were monitored, 6 in 1975–76 and 12 in 1977–78 (Table 4). In 1975–76, the radio-tagged birds were in the study area for periods of 5 to 63 days (average, 35 days). There were 158 radio locations and 11 visual sightings of tagged birds from 2 January to 23 March. There were no known transmitter failures or losses. In 1977–78, the radio-tagged eagles were in the study area for at least 6 to 75 days (average, 43 days). From 9 January through 6 April, there were 375 radio locations and 5 visual sightings of these 12 birds. During this period, three transmitter units failed and three others fell off the birds.

Radio-tagged eagles that stayed in the study area occupied Swan Lake NWR, Fountain Grove Wildlife Management Area, Pershing State Park, and bottomland along the Grand River (Fig. 1). Few radio locations were made in upland sites outside these four areas. Minimum estimated local winter ranges varied from 3.3 to 69.0 km² for radio-tagged eagles that remained on the study area for at least 22 days. Ranges encompassed most waterfowl concentration points within the entire study area, suggesting that eagle movements were strongly influenced by waterfowl dispersal patterns.

During both field seasons, movements of individual eagles varied greatly. Of the 18 radio-tagged birds, we located 6 only at Swan Lake NWR; 2 at Swan Lake NWR and bottomland along Grand River; 9 at Swan Lake NWR, Grand River bottomlands, and Fountain Grove Wildlife Management Area; and 1 at these three areas plus Pershing State Park. A few eagles frequently moved between Swan Lake and Fountain Grove, but generally the birds fed during the day and roosted at night on the same area. For example, in 1976 one eagle was on Swan Lake on 16 and 17 January, moved to Fountain Grove on 19 January for 3 days, moved back to Swan Lake for 2 days, returned to Fountain Grove for 16 days, and returned to Swan Lake for 14 days, until 24 February when it left the study area and radio contact was lost. Birds sometimes flew from Fountain Grove to feed on Swan Lake during the day, then returned to Fountain Grove to roost for the night. At other times, eagles fed on Swan Lake during the day and roosted near the river west of the refuge at night. Distances between feeding areas and night roost sites never exceeded 15.3 km.

Table 4. *Numbers of radio locations, visual sightings, days in study area, and minimum local winter ranges of radio-tagged bald eagles, Swan Lake National Wildlife Refuge, 1975–76 and 1977–78.*

Year, and eagle no.	Radio locations	Visual sightings	Days in area	Minimum range (km²)
1975–76				
1	4	0	5	18.9
2	34	4	63	69.0
3	5	1	11	13.8
4	24	3	30	26.1
5	33	3	39	55.1
6	58	0	61	42.5
1977–78				
7[a]	6	2	10	7.2
8[a]	2	1	6	–
9[b]	39	0	38	3.3
10	42	0	58	12.3
11	53	0	56	4.2
12	48	0	75	35.7
13	42	1	71	9.0
14[b]	31	0	38	11.9
15[a]	27	1	50	24.6
16[b]	40	0	46	32.8
17	20	0	22	19.6
18	25	0	47	31.2

[a]Transmitter unit stopped operating.

[b]Transmitter unit fell off eagle.

Discussion

Factors Influencing Chronological Patterns in Eagle Numbers

Bald eagles began arriving at Swan Lake NWR in early October and numbers increased as fall progressed. Numbers were greatest in early to middle December, but smaller peaks occurred throughout the rest of winter. Once migration was complete, the numbers of eagles on the refuge were related to availability of food. However, numbers of waterfowl (primarily geese), waterfowl hunting pressure, time of year, and weather also affected eagle numbers, often by influencing food availability. Figure 4 shows the relation of eagle numbers to Canada goose numbers on the refuge to time of year and, for 1975–76 and 1976–77, to numbers of carcasses of waterfowl and fish.

Although there were large numbers of Canada geese on the refuge by mid-October in each field season, numbers of bald eagles did not increase substantially until middle to late November. This lag in buildup of eagle numbers suggested that the number of Canada geese on the refuge had little effect on eagle numbers during fall and early winter. Eagle abundance was probably more dependent on proximate factors affecting the southward seasonal migration (discussed later). However, beginning in late November and continuing until the spring thaw, the occurrence of waterfowl at the refuge influenced eagle numbers. This was especially evident when there was an ice-free opening on otherwise frozen impoundments. Large numbers of waterfowl were attracted to the openings. During severe weather, many geese in open-water areas died, providing an important food source and attracting many eagles. Once the eagle migration was complete, eagle numbers in the study area were closely linked with numbers of waterfowl and fish carcasses.

In 1975–76, numbers of eagles on the refuge peaked 4 weeks after peak availability of waterfowl carcasses, but in 1976–77 the two peaks were roughly coincident. This apparent difference in chronologies probably reflects inaccuracies in our data on waterfowl carcass numbers. The important point is not the temporal relation between these two peaks, but the fact that after the fall influx, eagles were abundant whenever carcasses were available.

Secondary peaks following the major peak of eagle numbers in each field season were associated with thaws or other reasons for increased food availability. Eagle numbers increased after impoundments began to thaw and snow-covered waterfowl or fish carcasses were exposed. Mowing of refuge corn and milo fields in January of all three field seasons also increased eagle numbers by providing access to waterfowl carcasses. Eagle numbers declined when cold weather returned, freezing impoundments and covering carcasses with snow. Radiotelemetry results suggested that these peaks reflected movement from

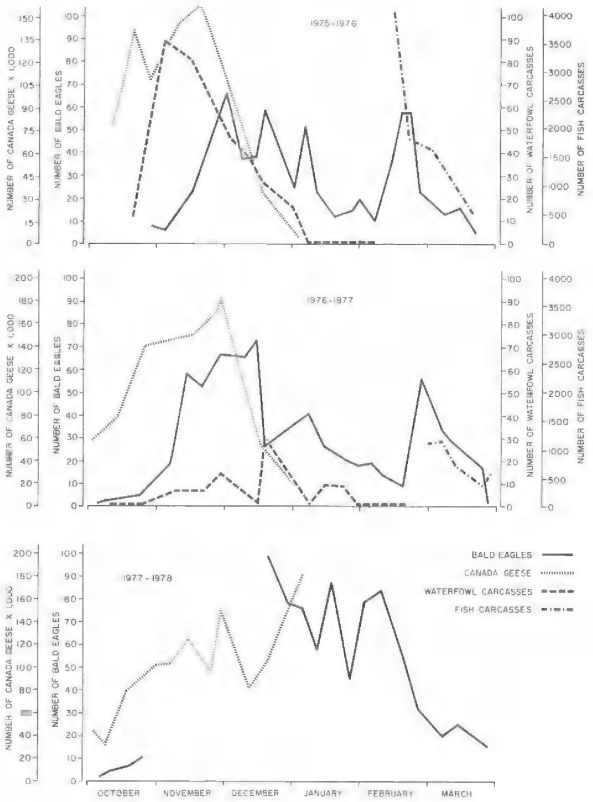

Fig. 4. Numbers of bald eagles wintering at Swan Lake National Wildlife Refuge related to abundance of Canada geese (1975–78) and waterfowl and fish carcasses (1975–77). (No eagle counts made 24 October to 19 December 1977.)

nearby areas rather than large-scale ingress or egress for the entire Swan Lake vicinity.

The average number of eagles on the refuge in the winter of 1977–78 was greater than the averages for the first two field seasons. The reasons for this increase are unknown but may be related to one or more of four factors: (1) increased severity of winter weather in 1977–78, forcing a larger percentage of the continental eagle population farther south; (2) increased continental numbers of bald eagles; (3) concentration of more eagles into fewer areas by destruction of winter eagle habitat; or (4) increased waterfowl use of the refuge and an extended goose hunting season in the Zone which probably increased the food available.

Factors Influencing Migration and Local Distribution of Eagles

Migrational Movements

Peak numbers of eagles at Swan Lake NWR occurred after large numbers of waterfowl had arrived on the

refuge, and sometimes long after waterfowl carcasses became available in substantial numbers. This late arrival of eagles on the refuge in relation to waterfowl and availability of food indicates that eagles probably remained at more northern areas until they were forced farther south. As Brown and Amadon (1968) indicated for most migrant birds of prey, food shortage was probably the major factor forcing the eagles south.

Numbers of Canada geese in the Swan Lake Zone peaked at about the same time during each year of the study, as did numbers of eagles on the refuge. The similar relation of goose and eagle peaks each year probably was not a cause-and-effect phenomenon, but reflected characteristic responses of each group of birds to factors influencing migration. We have no evidence that eagles were migrating with the major goose flocks in fall.

Complex food and habitat interactions occurred after goose and eagle numbers reached their peaks in December or early January. These interactions affected local movements and therefore numbers of geese and eagles on the study area throughout the rest of the winter.

During the first 2 years of this study, northward eagle migration coincided with the spring thaw in late February. As refuge impoundments became ice-free, large numbers of winter-killed fish became available to eagles. Although fish carcasses were abundant for at least 4 weeks after the thaw, eagle numbers began declining rapidly the second week after the thaw. In the third year, migratory movements were noted in mid-March, but a thaw had not occurred and there was little food available at the refuge during this period. Thus, the onset of spring eagle migration was not related to local food availability and did not always coincide with the local spring thaw.

Highly variable age ratios of the bald eagle population on the refuge throughout winter indicated a difference in seasonal movements of immature and adult birds. In fall, the presence of more immature than adult eagles indicated that some immature birds migrated south earlier than adults. In spring, adults began moving northward earlier than immatures. A rapid buildup and decline of adult birds occurred in mid-February; in contrast, numbers of immature birds, which also increased rapidly in middle to late February, remained relatively stable and then declined slowly as the early spring progressed. The wide variability in age ratios in fall and early spring indicated that eagles using the refuge during these periods were highly transient.

Local Movements

Daily and local movements of eagles on and off the study area were influenced strongly by the three interrelated factors of food availability, waterfowl distribution, and weather, among which food availability was the most important; however, availability of food often depended on locations of waterfowl concentrations, which in turn depended heavily on weather. Concentrations of eagles were highest where waterfowl concentrations were highest. Often when waterfowl left the refuge, they moved to the Grand River or farther south to the Missouri River. Eagles often followed the waterfowl and changed their roosting or feeding areas to correspond with the new sites that waterfowl were using. Waterfowl concentrations were ignored by eagles if fish from winter kills were available as in early spring 1975–76 and 1976–77.

The high ratio of adult to immature eagles during periods of harshest weather and lessened food availability on the refuge suggested that immatures may be less adept than adults at securing food, and may seek other areas not used by adults during these periods (Griffin 1981).

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